

# Distributive effects of new highway infrastructure in the Netherlands: the role of network effects and spatial spillovers

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Network effects and spatial spillovers are intrinsic impacts of transport infrastructure. Network effects imply that an improvement in a particular link in a network generates effects in many other elements of that network, while spillover effects can be defined as those impacts occurring beyond the regions where the actual transport investment is made. These two related effects entail a redistribution of impacts among regions, and their omission from road planning is argued to cause the systematic under-estimation of the profitability of transport projects and therefore the public financing they require. However, traditional transport appraisal methodologies fail to consider network and spillover effects. In this study we focus on the spillover impacts of two highway sections planned in the city region of Eindhoven, located in the Dutch province of Noord-Brabant, a region with traffic congestion problems. The new road infrastructure will be financed mainly by national government, the province and the urban region of Eindhoven ('*Stadsregio Eindhoven*'), which consists of 21 municipalities. We measure the benefits of the additional links in terms of travel time savings and the accompanying monetary gains. The results show that important spillovers occur in those municipalities close to the new links. The province of Noord-Brabant will benefit the most. We also found important spillovers in the province of Limburg. This latter province will benefit from reduced travel times without contributing financially to the establishment of the analysed new road links.

## 1. Introduction

Improvements in transport infrastructure are crucial in globalized economies, where flows of people, goods and information are key aspects to a country's competitiveness. The construction or upgrading of transport infrastructure cuts effective distance through travel time gains (Lakshmanan, 2011; Vickerman et al., 1999). For firms, the reduction of transport costs can extend markets and lead to economies of scale and specialization benefits (Forslund and Johansson, 1995). This has direct implications for overall operational costs but may also have indirect benefits with regard to, for instance, the storage of goods (Vickerman et al., 1999). Moreover, changes to regional competitive advantage due to transport infrastructure can result in firms formation and relocating in more accessible territories where they can benefit from

the advantages of spatial concentration and from proximity to innovation and knowledge (Holl, 2004, 2012; Melo et al., 2010). In addition, infrastructure investments can imply that people can move more rapidly, efficiently and using fewer economic resources, which increases the flow of people and goods. For workers, travel time savings can be translated into an increase in social and leisure activities or can lead to additional work-related opportunities. Travel time reliability can also increase, which is important in the context of the increasing role of just-in-time delivery and outsourcing processes in global markets but also from the viewpoint of passenger transport.

When evaluating the effects of transport infrastructure, it is important to consider the wider network effects and spillover effects. Network effects (Laird et al., 2005) imply that the improvement in a particular link in a network generates effects in other elements of that network. The network effect is intrinsically related to spillover effects, which we define here as those changes in travel times that occur beyond the regions where new transport investments are made. These effects represent a kind of distributive effect because they concern the redistribution of impacts among regions, something not usually included in transport appraisal. When an

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<sup>1</sup> The views expressed are purely those of the writer and may not in any circumstance be regarded as stating an official position of the European Commission.

investment is made to improve the transport infrastructure of a region, its benefits are spread to many other regions. Traditional methods such as Cost Benefit Analysis (CBA), despite being sound evaluation procedure in the public sector, have several limitations (Beuthe et al., 2000; Button, 1993; Vreeker et al., 2002) and rarely deal with the spatial redistribution of generated effects. Spillover analysis can offer some insights into the distribution of impacts across regions and can determine which regions benefit most from a transport project. Such insights can also be of interest from a funding perspective. In the Netherlands, as in many other countries, there has been a strong trend towards transferring certain responsibilities to more decentralized public institutions such as regions and municipalities. This also occurs within the field of major road infrastructure planning, where provinces and municipalities have gained in importance within the highway planning process alongside national government. Where they specifically focus on the integration of land-use and infrastructure developments, national government remains the main responsible agency from a transport network perspective. These greater local responsibilities may also result in greater financial contributions. Spillover effects could help us to understand how project costs could be distributed fairly according to accessibility gains.

In this paper we focus on studying the spillover impacts of two highway sections planned in the urban region of Eindhoven, in the southern Netherlands. This region has significant traffic congestion problems, which are expected to increase in the near future if no investments in road infrastructure are made. The benefits of the additional links will be measured in terms of travel time savings and the accompanying monetary gains, with a particular look at spillover effects. Previous studies have measured the spillovers of new transport infrastructure using accessibility measures (potential accessibility: see Condeço-Melhorado et al., 2011; Gutiérrez et al., 2010; López et al., 2009), but to our knowledge, this is the first time spillovers have been validated with actual mobility data. By weighting spillovers with traffic intensities it is possible to determine their true importance in terms of potential user benefit. Other novel aspects of this study are the monetization of spillovers according to traffic intensities and the value of travel time, and the use of spillovers as a possible indicator for determining how project costs could be distributed amongst different stakeholders.

The outline of this paper is as follows: Section 2 introduces the theoretical background of this study and is subdivided into two subsections. Section 2.1 provides insight into road infrastructure planning in the Netherlands, with a specific focus on financing responsibilities. Section 2.2 is an overview of the spillover concept used in this study and the importance of considering these effects in transport infrastructure appraisal. Section 3 considers the measurement of spillovers in transport infrastructure and is subdivided in two subsections, where 3.1 presents the case study and 3.2 defines the methodological steps. Section 4 presents impacts of the new road planned for the city region of Eindhoven, both in terms of travel time impacts (Section 4.1) and monetary and mobility impacts (Section 4.2). Finally, Section 5 presents our discussion and conclusions.

## 2. Who finances roads and who benefits?

### 2.1. Road infrastructure planning and financing in the Netherlands

In the Netherlands, national government plays an important role in the planning process for highway development. However, traditional approaches to major road infrastructure planning are changing towards the increased involvement and participation of regional and local public institutions in the planning process. This is part of a wider trend towards so-called area-oriented planning,

which integrates transportation objectives with further developments in a specific area, with the objective of improving sustainability by means of area-specific plans (Heeres et al., 2012). A more effective and efficient planning process could emerge through broader and earlier involvement of different but complementary – rather than conflicting – actor interests into the planning process. The road remains central to the planning process but additional developments are induced by these transport infrastructure developments (Arts and De Vaan, 2010). The idea behind closer cooperation with decentralized public agencies is that they have more expertise in the local context, know more about land-use opportunities and have greater options in land-use control. In practice, area-oriented planning often implies that national government remains involved in infrastructural projects, but that provinces and municipalities become more important and focus on the integration of land-use and infrastructure developments. The national government, on the other hand, mainly focuses on its responsibility for the main Dutch infrastructure network, to which individual highway projects belong.

Stronger regional and local responsibilities might translate into greater financial contributions yet regional and local budgets are often limited. However, with increased attention for area-oriented infrastructure planning, also financial contributions by decentral governments may increase. In addition to more common local and regional tax revenues, value capture mechanisms may be used to recoup and reinvest potential value increments (e.g., land values or house prices) caused by improved accessibility as a consequence of new or adjusted road infrastructure. Local and regional governments may use such money primarily to invest in the area around road infrastructure, for instance, to improve sustainability. They may, however, also use value increments to reinvest in road infrastructure itself such as to improve the business case of projects. Although Dutch examples of value capturing mechanisms in integrated highway and spatial development projects were recently described (see Heeres et al., 2013), the relevance of financial contributions by decentral governments may be even higher in countries where local municipalities and regions have greater responsibility and resources when it comes to road infrastructure development. In the light of the discussion, and, in addition to factors, such as formal responsibilities and the weight of regions and municipalities in terms of geographical and population size, we believe that spillover effects of new road infrastructure developments may provide an interesting additional perspective for looking at how projects costs could be distributed. Municipalities and regions that gain more from a new road in terms of travel time gains could, for instance, *ceteris paribus*, be asked to contribute more.

### 2.2. Accessibility and spillover effects

Traditionally, spillover effects have been measured by economic procedures motivated by Aschauer's study (1989a,b), which found a positive and significant influence of public capital stock, specifically that devoted to transport infrastructure, over regional productivity. Since then, transport infrastructure is thus regarded as an additional factor that can be used by firms to increase their productivity. Some studies (Cohen, 2010; Cantos et al., 2005; Delgado and Álvarez, 2007; García-Milá and McGuire, 1992) show evidence of spillover effects, defined as the positive effect of transport infrastructure that extends beyond the regional boundaries of where they are located.

Within this branch of literature there is a common procedure when measuring spillover effects that is to extend the public capital stock of a region to include the stock of neighbouring regions (Crescenzi and Rodríguez-Pose, 2008; Holtz-Eakin and Schwartz, 1995; Mas et al., 1994; Pereira and Sagalés, 2003). These studies assume that regional productivity benefits from the infrastructure

of that region but also from that of adjacent regions. They use a vicinity criterion, which considers that spillovers generated by transport infrastructure in neighbouring regions will be more intense. However, this assumption has certain limitations, most of which are pointed out in [Gutiérrez et al. \(2010\)](#). The vicinity criterion implies that the same weight is attributed to infrastructure located in all adjacent regions, yet they will have different roles depending on the direction and intensity of traffic flows. It may happen that some neighbouring regions are very important for cross-traffic flows while other regions are barely used for this purpose. The assignment of flows in a network cannot be captured by stock measures. Furthermore, the vicinity criterion only takes account of transport infrastructures located in adjacent regions which can lead to the overestimation of certain neighbouring infrastructure and underestimation of the infrastructure of non-adjacent regions. On the other hand the public capital stock variable is often criticized since it not a measure of service provided by (public) transport infrastructure but is mainly a construction cost measure. Instead, some authors recommend the use of accessibility measures ([Bruinsma and Rietveld, 1997](#); [Rietveld and Nijkamp, 1993](#)) arguing that these measures better represent the increased utility of transport infrastructure, such as more available opportunities.

As stated previously, the fact that spillovers depend on infrastructure characteristics is often not taken into account. When looking at road infrastructure it is clear that some roads are only used for internal traffic within a region – urban and local roads – whereas others have a crucial role in interregional flows, such as highways. Though public capital stock measures fail to capture aspects related to the performance of transport networks, these aspects can, however, be measured by network analysis and accessibility indicators. In this study we believe that accessibility measures are appropriate for measuring spillover effects of transport infrastructure. Despite being a common term, the accessibility concept has many definitions and many ways of measuring it (see for example [Geurs and Ritsema van Eck, 2001](#); [Geurs and Van Wee, 2004](#)). In this study, we follow the accessibility concept proposed by [Morris et al. \(1979\)](#), who defines accessibility as the ease with which activities can be reached from a certain place using a certain type of transport system.

Accessibility improvement is a direct consequence of transport upgrades and can thus be considered a main ‘product’ of transportation systems ([Schürmann et al., 1997](#)). The construction of transport infrastructure immediately impacts on an area’s accessibility conditions, reducing transport costs and increasing the regional advantages of that place. For that reason accessibility is an important variable for economic development as regions benefiting from high accessibility are usually richer and their inhabitants benefit from the proximity to the economic opportunities they need in their daily activities.

Improvements in transport infrastructure will impact accessibility in a wider transport network ([Laird et al., 2005](#)): the addition or improvement of a single link can significantly affect the demand and the performance of the whole network. The extent with which changes occur in the entire network is known as the network effect and spillovers are a consequence of these network effects. With some exceptions ([Gutiérrez et al., 2010](#); [López et al., 2009](#)), spillover effects are not included in transport assessment studies, although exclusion of these effects can be argued as resulting in the profitability of transport projects and therefore the public financing they require, being systematically underestimated.

On the other hand accessibility analyses are not fully exploited in policy evaluation ([Geurs and Ritsema van Eck, 2003](#); [Handy and Niemeier, 1997](#)). Some of the main reasons for this are the risk of double counting of effects ([Beuthe, 2002](#)) and the complexity of some accessibility measures, which complicate the subsequent

interpretation of results. Nevertheless, the inclusion of (good) accessibility as a political priority is gaining greater importance across developed countries. In the UK for example, accessibility is one of the five assessment criteria of the ‘New approach to appraisal’ (NATA) ([DETR, 1998](#)).<sup>2</sup> Accessibility and reliability are also key concepts in current Dutch policy (‘Nota Mobiliteit’; [Dutch Ministry of Transport, Public Works and Water Management, 2005](#); ‘Structuurvisie Infrastructuur en Ruimte’; [Dutch Ministry of Infrastructure and the Environment, 2012](#)). Furthermore, accessibility is considered vital at the EU level, as can be derived from the TEN-T policy, which is an important tool in connecting central and peripheral regions in Europe and towards achieving territorial and economic cohesion ([COM, 2009](#)).

In this study we look at spillover effects from the viewpoint of accessibility. Accessibility analysis can be used to estimate network effects as well as spillover effects defined here as the accessibility changes due to transport infrastructure developed in a different region. We added the adjective “spatial” in order to distinguish our approach to spillover effects assessed with traditional econometric models. With accessibility analysis we can overcome some of the drawbacks pointed out previously by capturing network effects of transport infrastructure and by including all the regions in the study area (not only the neighbouring ones).

### 3. Measurement of spatial spillovers of roads in Eindhoven

#### 3.1. Case study

##### 3.1.1. Description of the case study area: the current situation

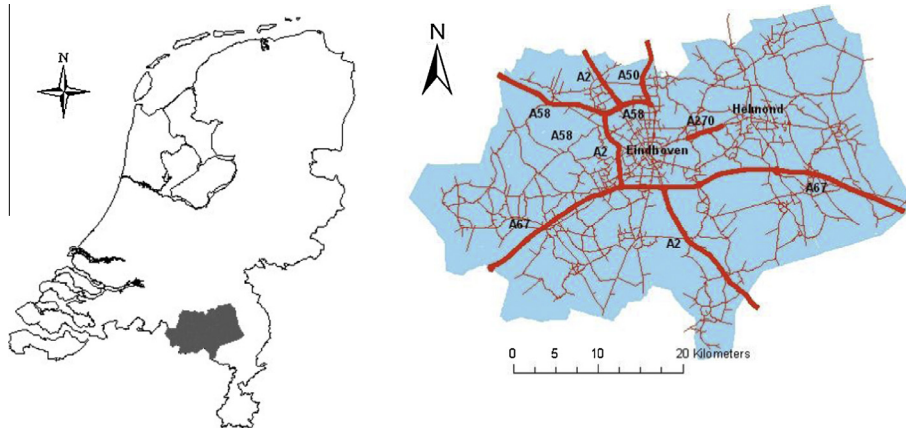
Our case study area is part of the Dutch province of Noord-Brabant in the south-eastern Netherlands (see [Fig. 1](#)), one of the twelve provinces of the Netherlands. This area is referred to as Zuid-Oostvleugel Brabantstad (‘BrabantCity South-eastern Wing’) or as Brainport Eindhoven, and is known as the Netherlands’ high-tech industry heartland (see [Fig. 1](#)). It consists of 21 municipalities represented by an inter-municipal cooperation board (the so-called SRE; ‘cooperation region Eindhoven’). Two major cities are located within the boundaries of the area. The bigger of the two is Eindhoven, with about 217,000 inhabitants, the smaller is Helmond, with a population of about 89,000 (see [CBS Statistics Netherlands, 2012](#)).

Currently, several motorways cross the area, all converging in Eindhoven (see [Fig. 1](#)). The motorways in the area are notorious for their traffic jams: as a consequence, there are long-lasting accessibility problems. Because Eindhoven has no eastern ring road, accessibility in the region is vulnerable to incidents that can hinder traffic flow on the western ring road, i.e. the A2.

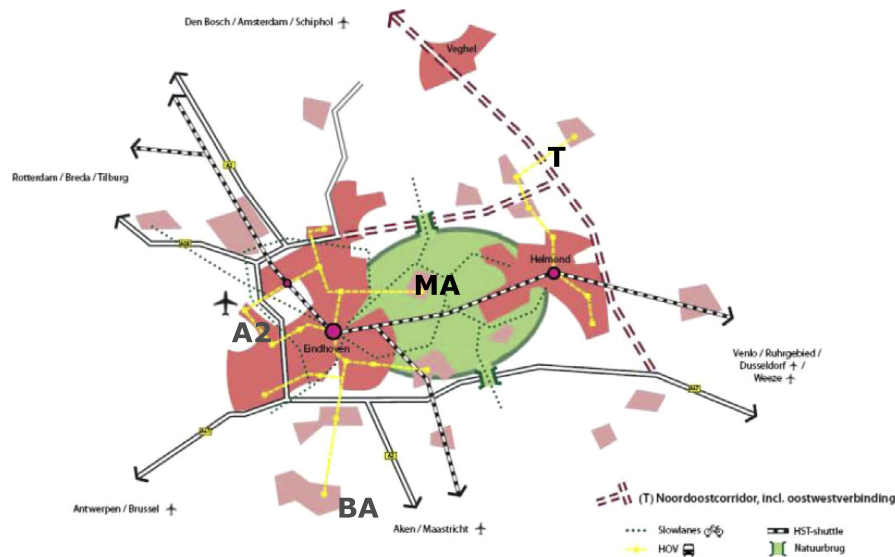
##### 3.1.2. Plans for the near future: towards an area-oriented approach

After a long lasting and great deal of discussion on the need to improve accessibility, especially by means of a north–south connection in eastern Eindhoven, in 2006, the provincial government of Noord-Brabant enforced a regional approach with a broad, area-oriented plan with traffic, spatial planning and economic issues as its starting point: “The Zuidoostvleugel development programme”. This programme (see [Dutch Ministry of Infrastructure and the Environment, 2011](#)) consisted of mutually linked developments in four main areas: the north-east corridor (abbreviated as ‘the T’, because of its shape), the Middle Area (MA), the A2-zone, and the Boarder Area with Belgium (BA) (see [Fig. 2](#)). The province acted as a process manager for ‘the T’ and the BA, while the

<sup>2</sup> However, accessibility in NATA follows a different approach from the one presented here, since it is specifically focused on the segregation impact of transport networks in local communities.



**Fig. 1.** Case study area; left: study area shaded in grey as part of the Netherlands; right: SRE study area with network links and major cities.



**Fig. 2.** 'Zuidoostvleugel BrabantStad' case in a nutshell.

municipal cooperation board of Eindhoven (SRE) performed this role in the MA and the A2-zone. 'The T' concerns the development of the missing eastern and northern parts of the ring road around Eindhoven, also known as the 'Ruit' (diamond): this will be a 4-lane 100 km/h road. In addition, new road development in the north to Veghel is part of the plans. The MA will function as a recreational green area, thereby constraining the development of new urban functions such as housing. Two nature connection zones will connect the MA area with the natural habitat to the north of the to be extended A58 and with the area below the A67 highway. A further part of the plans is to downgrade highway A270 between Helmond and Eindhoven to a regional road with speed limits of 80 or 100 km/h instead of the current 120 km/h, and also to downgrade two (other) local/regional roads within the MA area to stimulate drivers to use the new T-structure.

After the regional agreement was reached in 2007, a pilot study was started in 2008. At that moment the national government also positively evaluated the programme and gave a financial commitment of EUR 259 million to developing the T-structure (i.e. completing the Eastern and Northern ring structure). The total costs of the T-structure part are estimated at EUR 815 million (Dutch Ministry of Infrastructure and the Environment, 2011), which means that the region, both the 21 SRE municipalities and the

province of Noord-Brabant have to contribute significantly. The project is now in the planning stage and the exact provincial and municipal financial contribution is still unclear.

### 3.2. Modelling procedure

The two new roads are shown in Fig. 3. The northwest-south-east link of approximately 68 km is an improvement of the existing N279, whereas the west-east link is a totally new construction of about 32 km. These roads cross several municipalities, as can be seen in Table 1.

In this paper we consider the effects of these roads in terms of accessibility and mobility improvements, with a particular focus on the spillover effects generated. To do so, we compiled a data set about the location where trips have their origin and destination as well as the network links used. The study area contains 4026 four digit postcodes in the Netherlands, with their centroids representing the places of origin, and we selected a set of 34 'prominent cities' surrounding Eindhoven as destinations, 10 of which are located in Germany, 10 in Belgium and the remaining 14 in the Netherlands (Fig. 4). By selecting these 34 cities we ensure that the relationships we are looking at are economically significant. Furthermore the use of postcodes has the main advantage of



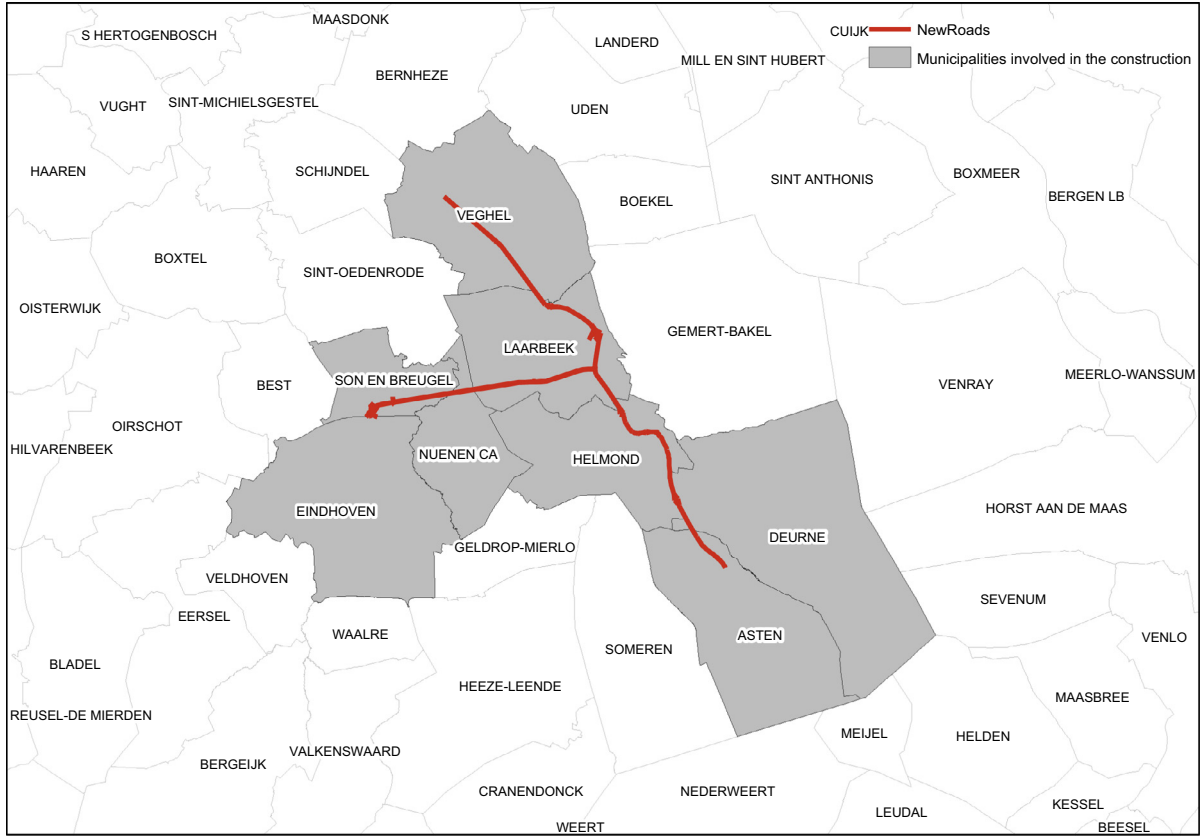


Fig. 3. Location of the new roads selected as case studies.

**Table 1**  
Municipalities involved in the construction process.

Municipalities	km of new roads
Laarbeek	27.3
Son en Breugel	13.4
Helmond	12.5
Nuenen Ca	2.5
Veghel	8
Asten	2.9
Eindhoven	0.3
Deurne	1.2

capturing more spatial variability of effects than if we would use more aggregates zones (e.g. municipalities or provinces). For the network analysis we used a digital road network, which includes a total of 48,073 arcs and which covers the Netherlands, part of Germany and Belgium. The network has more geographical detail in the province of Noord-Brabant, where most of the impacts are expected to occur. Each arc contains information about the type of road, the free flow speed, capacities and loads.

Considering the traffic congestion levels in this area, it is important to correctly measure the effects of the new roads on traffic redistribution. Two simulation models are used to achieve this: a dynamic traffic assignment model called INDY (Bliemer et al., 2004), which can realistically simulate traffic flows and traffic congestion, and a GIS called Flowmap (Breukelman et al., 2009). Basically, INDY uses the network data about road type, speeds in free flow, capacities and traffic intensities to estimate route travel times before and after the construction of a new road. Within the model, two alternatives were simulated for the morning peak period: one base scenario without the new roads and one scenario with the planned T-structure in combination with a downgrade

of highway A270 between Helmond and Eindhoven to a regional road. The model allowed for changes to occur in trip distribution and modal split between both scenarios. This means that because of changes in the network and accompanying changes in travel impedances, certain OD-relationships may become more or less preferable compared with the base scenario. However, the sum of all trips remained unaltered, i.e. the total number of trips in the origin- destination (OD) matrix summed up for all different transport modes. Outputs from the traffic model, in the form of travel times per network link, are used as input for Flowmap to obtain origin destination travel time matrices, taking postcodes as origins and the 34 selected cities as destinations.

For each postcode, the travel time needed to reach each particular city is measured on the basis of two scenarios:

- A *reference scenario*, which represents the road network before the construction of new roads.
- A *future scenario* that simulates the completion of these new roads.

We first compute the mean travel time changes (MTTC) in relative terms for each postcode, by comparing the travel times ( $T$ ) estimated for the future scenario ( $t1$ ) with those computed for the reference situation ( $t0$ ) between a postcode  $i$  and a city  $j$ , according to:

$$MTTC_i = \sum_{j=1}^n \left( \frac{(T_{ij,t1} - T_{ij,t0}) * 100}{T_{ij,t0}} \right) / n \quad (1)$$

where  $n$  is the number of destination cities (34 in total). This indicator yields an indication of the average impact of the new road infrastructure on travel time. A negative value indicates a reduction

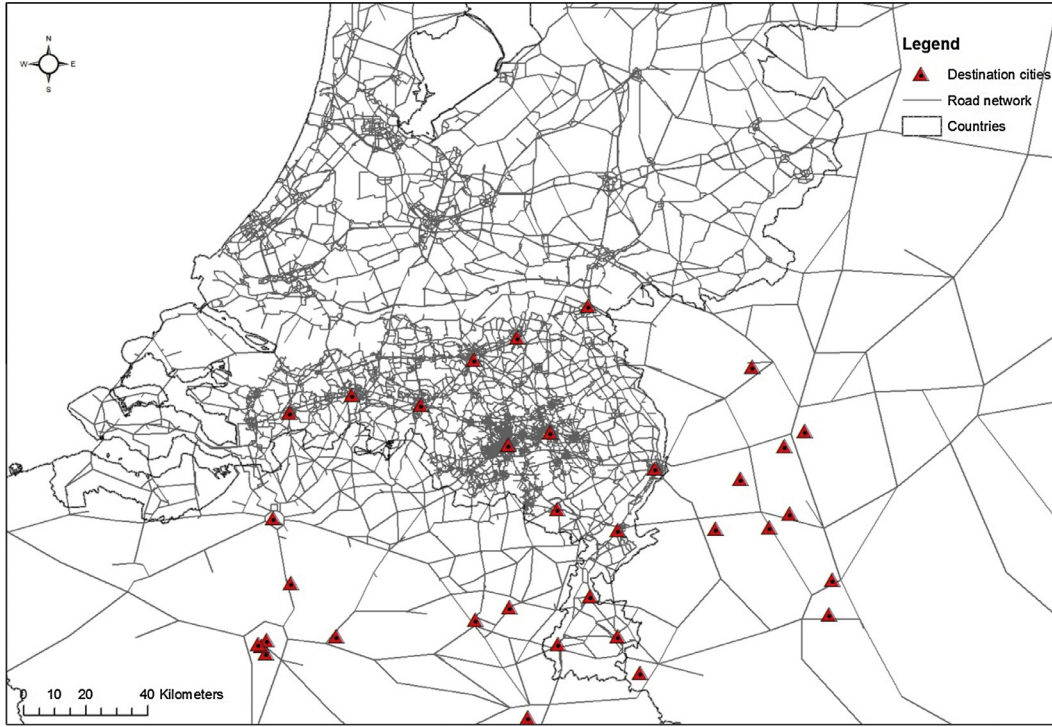


Fig. 4. Destination cities and the road network.

**Table 2**  
Descriptive statistics of travel time reductions (%) at postcode level (mean travel time changes – Eq. (1)).

	All postcodes	Postcodes receiving the infrastructure	Postcodes not receiving the infrastructure
Count	4026	16	4010
Minimum	–2.9	–2.9	–2.9
Maximum	1.3	–0.9	1.3
Mean	–0.03	–1.0	–0.03
Standard Deviation	0.25	1.1	0.2

in travel time due to the new roads, which can be interpreted as an increase of the accessibility from a postcode (i.e. the origin) to the selected cities. This represents a meaningful measure of the accessibility impacts since it entails an access change from each postcode to major destinations.

In addition to the indicator above, we aim to gain greater insight into where the highest time gains (and thus benefits<sup>3</sup>) of the new road infrastructure are to be expected. Our second indicator represents the highest travel time gains as a consequence of the additional infrastructure for each postcode zone  $i$ :

$$HTTC_i = Highest_{ij} \left( \frac{(T_{ijt1} - T_{ijt0}) * 100}{T_{ijt0}} \right) \quad (2)$$

where  $HTTC_i$  is the highest travel time benefit in relative terms for postcode  $i$ ,  $Highest_{ij}$  is the maximum negative travel time change concerning all relationships between  $i$  and the 34 destination cities  $j$ . For each postcode, this indicator provides information about the size and location of the highest potential travel time benefits. Both indicators target the postcode level. Moreover, we also looked at a

municipal and even a provincial level because sometimes it is politically more significant, as these institutional bodies are involved in the planning process and in the construction of roads. When doing this we average the mean or the highest travel time gains (Eqs. (1) and (2)) of all postcodes inside each municipality or province.

Moreover, we analyse the impacts of the new road in monetary terms, because it can provide an indication of how projects costs could be distributed amongst different stakeholders. The value of travel time changes (V TTC) between each municipality  $k$  and destination city  $j$  is calculated by crossing information about travel time differences between  $k$  and  $j$  ( $TTD$ , calculated as  $Tk_{jt0} - Tk_{jt1}$ , in minutes, where  $Tk_{jt}$  is the mean travel time change achieved by all postcodes inside a municipality  $k$  to a destination city  $j$ ),<sup>4</sup> traffic intensities ( $TI$ ) between  $k$  and  $j$  and a value of travel time (VOT), according to:

$$V TTC_{kj} * TI_{kj} * VOT \quad (3)$$

Because traffic intensities were available only for the Netherlands, we restricted these results to only 14 destinations, i.e. cities located in the Netherlands. We used estimated daily traffic intensities for the plan year, which includes the T-structure around Eindhoven. Moreover, we applied three different VOTs (5; 11 and 20 EUR per hour) to cover diverse social groups. We based our average VOT of 11 EUR/h on Van Amelsfort and Bliemer (2006), who estimated this value on the basis of data from a stated choice experiment in which respondents had to trade off alternative commute journeys under road pricing conditions. The other two values were chosen quite arbitrarily as rounded minimum and maximum values. The total value of travel time changes by each municipality ( $V TTC_k$ ) is calculated as:

$$V TTC_k = \sum_{j=1}^j V TTC_{kj} \quad (4)$$

<sup>3</sup> We implicitly assume that travel time gains bring benefits. Although this is a common assumption, travel time gains only bring benefits if the time saved can be used usefully (in an economically beneficial way).

<sup>4</sup> Note that positive values indicate that travel times were reduced, while in Eqs. (1) and (2) these were expressed as negative values.

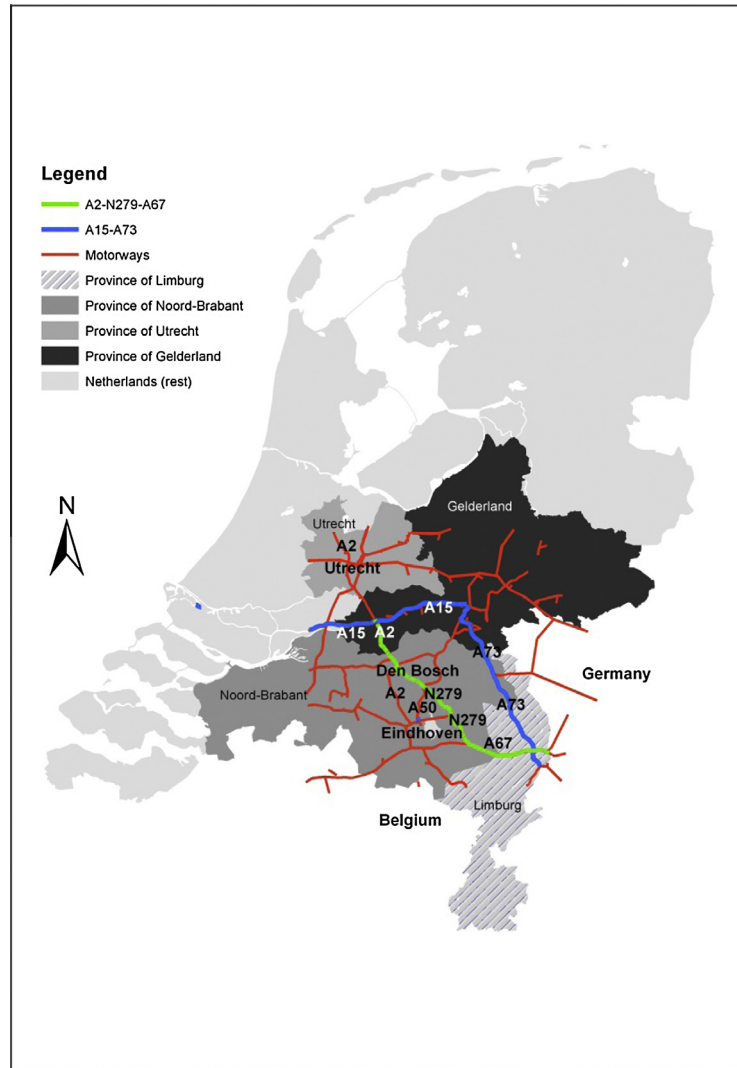


Fig. 5. Dutch provinces and main motorways around T-structure.

#### 4. Travel time, monetary and mobility impacts of the new road infrastructure

##### 4.1. Travel time impacts

Table 2 presents some descriptive statistics about the impacts of the two new roads expressed as mean travel time changes. These results were calculated using Eq. (1) and represent the mean travel time change for each postcode (in the Netherlands) when accessing the entire set of destination cities. Globally, the mean travel time change is negligible (i.e.  $-0.03\%$ ), denoting that improvement of the transport infrastructure at a national level has a slightly positive effect on travel times. Travel time decreases occur mainly in those postcodes where new roads are built and for those origin–destination relationships for which it is likely to use the new T-structure. The highest average travel time decrease for an origin postcode to all 34 destinations amounts to almost 3%. Changes occurring outside those postcodes receiving the infrastructure can be regarded as spillover effects. Table 2 shows that these spillovers are lower than travel time reductions inside the area where new roads are constructed.

Some postcodes outside the construction area register a slight increase in travel times. This occurs mainly for relations between Eindhoven and Helmond at the east, and, is caused by the

impairment of the highway A270 between Helmond and Eindhoven, and, the additional downgrading of two local/regional roads within the MA area (see Fig. 2), which are meant to stimulate drivers to use the new T-structure. Moreover, we observed a small accessibility decrease between the cities of Utrecht and Den Bosch, which are both well outside the area where the road structure is planned. Further examination of traffic intensities from the model output indicated that part of the upgraded T-structure, i.e. the N279, is used more intensively by traffic between the western part of the Netherlands and the German-Ruhr area (see Fig. 5). Whereas in the base-scenario the most likely trip path was to take the A15–A73 combination, the infrastructure adjustments also make some trips being diverted to the path A15–A2–N279–A67. Especially on the A2 stretch between Utrecht and Den Bosch this results in a slight decrease in accessibility.

Analysing spillovers at a postcode level has minor political significance, because municipal boards and, at a higher level, provinces and the national government are the responsible institutional agencies involved in major road project planning. We therefore also analysed spillovers at the municipal (see Table 3) and provincial level. The results at the municipal level are generally in line with those observed in Table 2, although the minimum and maximum values are less extreme because of the aggregation from postcode to municipal level. As we already pointed out, some areas

**Table 3**

Descriptive statistics of travel time reductions (%) at municipal level (mean travel time changes – Eq. (1)).

	All municipalities	Municipalities receiving the infrastructure	Municipalities not receiving the infrastructure
Count	443	8	435
Minimum	-2.2	-2.2	-1.8
Maximum	0.9	0.9	0.5
Mean	-0.04	-0.5	-0.03
Standard Deviation	0.3	1	0.2

**Table 4**

Descriptive statistics of travel time reductions (%) at postcode level (highest travel time changes – Eq. (2)).

	All postcodes	Postcodes receiving the infrastructure	Postcodes not receiving the infrastructure
Count	4026	16	4010
Minimum	-24.5	-24.5	-20.3
Maximum	-0.2	-3.8	-0.2
Mean	-3.2	-15.0	-3.2
Standard Deviation	2.5	5.5	2.4

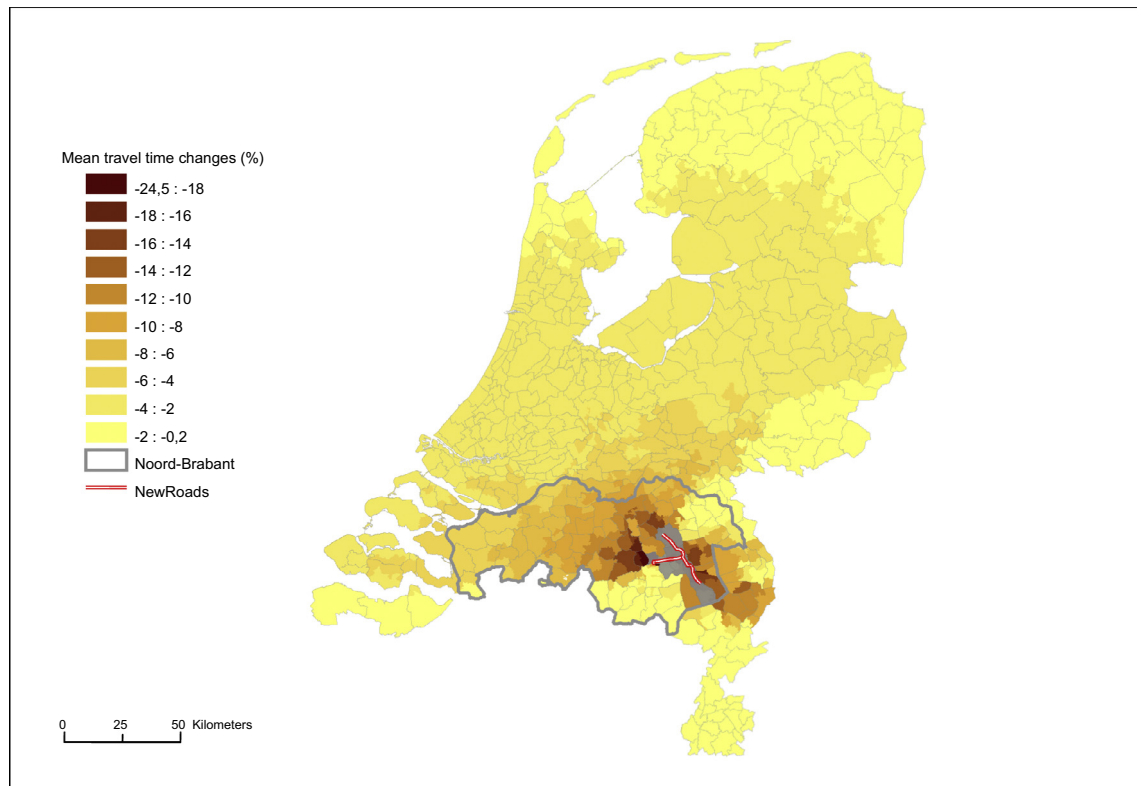
register a slight increase in travel time as a consequence of induced traffic. Generally speaking, however, averaged over all Dutch municipalities there is a small travel time decrease. As expected, at regional level, the province of Noord-Brabant registers the greatest travel time reductions, because it contains the new T-structure. However, important ‘positive’ spillovers can also be found in the north of the province of Limburg and to a lesser extent in the south of the province of Gelderland.

We obviously obtain a more positive picture with the second indicator – the highest travel time gain – because it focuses on the highest travel time reduction achieved by each postcode to any of the selected cities. On average we observe a travel time reduction of approximately 3% (Table 4), while in some areas, especially where the new road links are located, this decrease amounts to almost 25%. However, in some postcodes outside the construction area, we observe significant effects of up to 20%, which emphasizes the importance of taking account of spillovers. At a somewhat higher spatial scale, i.e. municipalities, we found comparable results to those at the postcode level.

Fig. 6 also shows the results of Eq. (2), graphically at a postcode level. This figure shows that spillovers are greater at the end of the links, following a northwest-southeast distribution for the old N279, and a west–east distribution for the new west–east link. This is in line with previous studies (Gutiérrez et al., 2010; Condeço-Melhorado et al., 2011), which found that orientation and distance to new links are an important factor influencing spillover magnitude. Finally, we note that the west–east link seems to generate greater spillovers than the other link, which is in line with expectations, because the west–east link is a new connection, whereas the other is an improvement of partly already existing road links (i.e. the N279).

#### 4.2. Monetary and mobility impacts

In this section we translate traffic intensities and express travel time changes into monetary values (see Eq. (3)) at municipal level. Table 5 shows descriptive statistics of the value of travel time changes for all municipalities in the Netherlands. In line with earlier results, some municipalities show a loss, while the new transport infrastructure results in a gain for other municipalities, up to a maximum between approximately EUR 1000 (VOT = 5 EUR/h) and EUR 4000 (VOT = 20 EUR/h) per day. For the whole country, the



**Fig. 6.** Spillover effects of two new roads in Eindhoven (highest travel time change).



**Table 5**

Value of travel time changes (EUR/day) for all municipalities in the Netherlands (Eq. (4)).

Descriptives	VOT 5 EUR/h	VOT 11 EUR/h	VOT 20 EUR/h
Count	443	443	443
Minimum	-820	-1807	-3289
Maximum	983	2167	3944
Sum	2841	6260	11,392
Mean	6	14	26
Standard Deviation	93	205	372

**Table 6**

Value of travel time changes (EUR/day) by provinces.<sup>a</sup>

Provinces	VOT 5 EUR/h	VOT 11 EUR/h	VOT 20 EUR/h
Drenthe	1	2	4
Flevoland	-17	-38	-69
Friesland	-4	-9	-17
Gelderland	-214	-472	-858
Groningen	0	1	1
Limburg	1043	2299	4183
Noord-Brabant	2407	5306	9655
Noord-Holland	-127	-280	-509
Overijssel	5	10	19
Utrecht	-127	-281	-511
Zeeland	7	15	27
Zuid-Holland	-133	-293	-534

<sup>a</sup> These values are calculated as the sum of the value of travel time changes (Eq. (4)) in all municipalities inside each province.

new T-structure represents a gain ranging from slightly less than EUR 3000 to more than EUR 11,000 per day, while the average gain by municipality ranges from a modest EUR 6 to EUR 26 per day. In line with Section 4.1, we again find that some municipalities lose. The losses are smaller, however, than the gains.

Furthermore, we analysed which bilateral relationships gain. The ones most benefited either originate or end up in's Hertogenbosch and/or Helmond; they make full use of the benefits of the new T-structure. Another connection that scores well is the internal relationship within Eindhoven. This latter result is not so much due to the absolute size of the travel time gain but is rather caused by small travel time gains in combination with high traffic intensities. Finally, Table 6 shows the value of travel time changes by province. As expected, the province of Noord-Brabant benefits most. However, the benefits measured for the province of Limburg are noteworthy and account for approximately 40% of the benefits achieved by Noord-Brabant. The likely reason for this is that the new T-structure is located close to Limburg.

## 5. Conclusions

When evaluating the effects of transport infrastructure spillover effects must be considered. The exclusion of these effects can be argued to cause the underestimation of the profitability of transport projects and therefore the public financing they require. Previous studies have measured spillovers (Condeço-Melhorado et al., 2011; Gutiérrez et al., 2010; López et al., 2009) of new transport infrastructure with accessibility measures (potential accessibility), but this is the first time spillovers have been validated with mobility data. The main contribution of this paper is the estimation of spillover effects caused by two new roads planned for the city region of Eindhoven and weighting these with traffic intensities. It was thereby possible to determine their true importance with respect to their benefit for potential users. Another novel aspect of this study was the monetization of spillovers according to traffic intensities and the values of travel time.

The effects of the new roads were expressed in travel time changes and in monetized time changes. Regarding the former, two measures were used: (1) the mean travel time change (both gains and losses) and (2) the highest travel time decrease (i.e. benefit) for each postcode to a set of cities. Our results indicated that the greatest travel time decreases occur in municipalities that contain new roads. With respect to spatial orientation, we find that spillovers are more intense at the end points of the new roads. However, some nearby locations obtain only a marginal benefit because they still have other alternative roads that are more useful for reaching important neighbouring cities. Additionally, we monetized the travel time changes by means of values of travel time change and by considering traffic intensities. This resulted in a generally positive effect for the new roads. Within the analysis in this paper, the sum of all trips remained unaltered as a consequence of new road infrastructure. This is a valid assumption on the short run. On the longer term, trip generation may occur because of additional road capacity, which may result in a greater number of trips, but potentially also in additional traffic delays compared to a situation without trip generation. In such case, the analysis in monetary terms may be a better indicator for assessing spillover effects compared to the travel time indicator, because the former indicator mentioned takes account of both travel time changes and traffic intensity effects. This would give more balanced insight into the spillover effects under conditions of traffic generation.

In our analysis we also distinguished between different spatial and institutional levels: the postcode level, municipalities and provinces. Although the general picture is in accordance with expectations, we found that the magnitude of spillovers decreases as the spatial unit of analysis increase. Spillovers are greater at the postcode level, since neighbouring postcodes are closer to transport investments, while with larger spatial units, such as provinces, neighbouring regions are located further away from the actual investment area and local extremes are averaged out.

We conclude that, from a travel time perspective, areas that are closer to where new road infrastructural investments are made generally benefit more. Considering the provincial scale, this logically means that the province of Noord-Brabant will benefit more from the T-structure than other Dutch provinces, although the province of Limburg, which is located to the southeast of Noord-Brabant, also receives important gains due to spillovers.

Spillover effects could shed different light on current infrastructure investments and on where the money streams should come from. As addressed in Section 3.1, the current plan is that the national government in the Netherlands, the province of Noord-Brabant and the 21 municipalities located within the 'cooperation region Eindhoven' (SRE) all contribute financially. The T-structure project is still at the planning stage and currently only the national government's contribution has been decided upon: EUR 259 million. The remaining budget has to come from regional partners. The 21 SRE municipalities and the province of Noord-Brabant are those that stand to benefit most according to our travel time spillover analysis. From this point of view their financial contribution seems logical. However, our analysis also showed that several other regions outside Noord-Brabant benefit. The region to benefit most significantly is Limburg, located southeast of Noord-Brabant.

From a travel time 'fairness' perspective, Limburg should contribute financially to the realisation of the T-structure, given the spillover gains that it gets in return. In practice, however, this may not be so easy to achieve. Other regions or municipalities may not be that willing to contribute to new road infrastructure constructed in another region, because they may want to use their limited financial resources for road projects (or to achieve other policy goals) in their own region. They may for instance also claim, fairly or unfairly, that another region substantially benefits from their road infrastructure as well. However, although the current

financing system in the Netherlands, with a prominent role for national government, could be hard to adjust, and, although it may be difficult to have different regional stakeholders to agree on co-financing issues, our spillover analysis at least provides interesting insight into how financial responsibilities could be distributed differently, and, depending on the perspective taken, more fairly. A notable example of extraordinary financial cooperation is the construction of a section of the Bundesautobahn 31 (or A31), which runs between the Ruhr area and the city of Emden in Germany, parallel to and near the Dutch border. A small stretch of this road between Ochtrup and Lingen was completed ahead of schedule because of a regional Dutch financial contribution. The reason for this contribution was that the A31 connects cities in the east and north-east of the Netherlands with the German Ruhr area. Such financial constructions could also be applied in other cases, such as in countries with more decentralized road infrastructure planning, and accessibility spillovers could provide a useful insight into how to shape these constructions.

Arts, J., De Vaan, M., 2010. Infrastructure meets area development. Developments in Dutch planning practice: towards a more balanced finance of development projects? In: Fourth Conference on Planning Law and Property Rights. Dortmund, Germany.

Aschauer, D.A., 1989a. Is public expenditure productive? *Journal of Monetary Economics* 23, 177–200.

Aschauer, D.A., 1989b. Does public capital crowd out private capital? *Journal of Monetary Economics* 24, 171–188.

Beuthe, M., 2002. Transport evaluation methods: from cost–benefit analysis to multicriteria analysis and the decision framework. In: Giorgi, L., Pearman, A. (Eds.), *Project and Policy Evaluation in Transport*. Ashgate, Aldershot.

Beuthe, M., Eeckhoudt, L., Schannella, G., 2000. A practical multicriteria methodology for assessing risky public investments. *Socio-Economic Planning Sciences* 34, 121–139.

Bliemer, M.C.J., Versteeg, H.H., Castenmiller, R.J., 2004. INDY: a new analytical multiclass dynamic traffic assignment model. In: *Proceedings of the TRISTAN V Conference*. Guadeloupe.

Breukelman, J., Brink, G., De Jong, T., Floor, H., 2009. Manual Flowmap 7.3. Faculty of Geographical Sciences, Utrecht University, Utrecht.

Bruinsma, F.R., Rietveld, P., 1997. The Impact of Accessibility on the Valuation of Cities as Location for Firms. Free University Amsterdam, Amsterdam.

Button, K.J., 1993. *Transport Economics*. Cambridge University Press, Cambridge.

Cantos, P., Gumbau-Albert, M., Maudos, J., 2005. Transport infrastructures, spillover effects and regional growth: evidence of the Spanish case. *Transport Reviews* 25, 25–50.

CBS Statistics Netherlands, 2012. <<http://statline.cbs.nl>>.

Cohen, J.P., 2010. The broader effects of transportation infrastructure: spatial econometrics and productivity approaches. *Transportation Research Part E: Logistics and Transportation Review* 46, 317–326.

Commission of the European Communities (COM), 2009. Green Paper – TEN-T: A Policy Review – Towards a Better Integrated Trans-European Transport Network at the Service of the Common Transport Policy. 44 Final. Brussels.

Condeço-Melhorado, A., Gutiérrez, J., García-Palomares, J.C., 2011. Spatial impacts of road pricing: accessibility, regional spillovers and territorial cohesion. *Transportation Research Part A* 45, 185–203.

Crescenzi, R., Rodríguez-Pose, A., 2008. Infrastructure endowment and investment as determinants of regional growth in the European Union. *European Investment Bank Papers* 13 (2), 62–101.

Delgado, M.J., Álvarez, I., 2007. Network infrastructure spillover on private productive sectors: evidence from Spanish high capacity roads. *Applied Economics* 39, 1583–1597.

DETR, 1998. A New Deal for Trunk Roads in England: Understanding the New Approach to Appraisal (NATA). Department of the Environment, Transport and the Regions, London.

Dutch Ministry of Infrastructure and the Environment, 2011. MIRT Projectenboek 2012. Ministry of Infrastructure and the Environment, The Hague, The Netherlands.

Dutch Ministry of Infrastructure and the Environment, 2012. Structuurvisie Infrastructuur en Ruimte (SVIR) –Nederland concurrerend, bereikbaar, leefbaar en veilig [Structure Vision Infrastructure and Space – The Netherlands Competitive, Accessible and Safe]. Ministry of Infrastructure and the Environment, The Hague, The Netherlands.

Dutch Ministry of Transport, Public Works and Water Management, 2005. Nota Mobiliteit, Naar een betrouwbare en voorspelbare bereikbaarheid [National Mobility Plan, Towards a Dependable and Predictable Accessibility], Deel III Kabinetsstandpunt. Ministry of V&W, The Hague, The Netherlands.

Forslund, U.M., Johansson, B., 1995. Assessing road investments: accessibility changes, cost benefit and production effects. *Annals of Regional Science* 29, 155–174.

García-Milá, T., McGuire, T.J., 1992. The contribution of public provided inputs to states 'economies'. *Regional Science and Urban Economics* 22, 229–241.

Geurs, K.T., Ritsema van Eck, J.R., 2003. Evaluation of accessibility impacts of land-use scenarios: the implications of jobs competition, land-use, and infrastructure developments for the Netherlands. *Environment and Planning B: Planning and Design* 30, 68–87.

Geurs, K.T., Ritsema van Eck, J.R., 2001. Accessibility Measures: Review and Applications. RIVM Report 408 505 006. <[http://www.pbl.nl/en/publications/2001/Accessibility\\_measures\\_review\\_and\\_applications](http://www.pbl.nl/en/publications/2001/Accessibility_measures_review_and_applications)>.

Geurs, K.T., Van Wee, B., 2004. Accessibility evaluation of land-use and transport strategies: review and research directions. *Journal of Transport Geography* 12, 127–140.

Gutiérrez, J., Condeço-Melhorado, A., Martín, J.C., 2010. Using accessibility indicators and GIS to assess spatial spillovers of transport infrastructure investment. *Journal of Transport Geography* 18, 141–152.

Handy, S.L., Niemeier, D.A., 1997. Measuring accessibility: an exploration of issues and alternatives. *Environment and Planning A* 29, 1175–1194.

Heeres, N., Tillema, T., Arts, J., 2012. Integration in Dutch planning of motorways: from "line" towards "area-oriented" approaches. *Transport Policy* 24, 148–158.

Heeres, N., Tillema, T., Arts, J., 2013. Value capture around road infrastructure as an alternative means to promote public–public cooperation? In: *PLPR Conference*, February 2013, Portland, Oregon, USA.

Holl, A., 2004. Manufacturing location and impacts of road transport infrastructure: empirical evidence from Spain. *Regional Science and Urban Economics* 34, 341–363.

Holl, A., 2012. Market potential and firm-level productivity in Spain. *Journal of Economic Geography* 12, 1191–1215.

Holtz-Eakin, Schwartz, D., 1995. Spatial productivity spillovers from public infrastructures: evidence from state highways. *International Tax and Public Finance* 2, 459–468.

Laird, J.J., Nellthorpe, J., Mackie, P.J., 2005. Network effects and total economic impact in transport appraisal. *Transport Policy* 12, 537–544.

Lakshmanan, T.R., 2011. The broader economic consequences of transport infrastructure investments. *Journal of Transport Geography* 19, 1–12.

López, E., Monzón, A., Ortega, E., Mancebo, S., 2009. Assessment of cross-border spillover effects of national transport infrastructure plans: an accessibility approach. *Transport Reviews* 29, 515–536.

Mas, M., Maudos, J., Pérez, F., Uriel, E., 1994. Capital público y productividad en las regiones españolas. *Moneda y Crédito* 198, 163–193.

Melo, P., Graham, D., Noland, R., 2010. Impact of transport infrastructure on firm formation. *Transportation Research Record: Journal of the Transportation Research Board* 2163, 133–143.

Morris, J.M., Dumble, P.L., Wigan, M.R., 1979. Accessibility indicators for transport planning. *Transportation Research Part A: General* 13, 91–109.

Pereira, M.A., Sagalés, O.R., 2003. Spillover effects of public capital formation: evidence from the Spanish regions. *Journal of Urban Economics* 53, 238–256.

Rietveld, P., Nijkamp, P., 1993. Transport and regional development. In: Polak, J., Heertje, A. (Eds.), *European Transport Economics*. European Conference of Ministers of Transport (ECMT), Oxford.

Schürmann, C., Spiekermann, K., Wegener, M., 1997. Accessibility Indicators. Dortmund: Berichte aus dem Institut für Raumplanung. IRPUD, Report Number, 39.

Van Amelsfort, D.H., Bliemer, M.C.J., 2006. Alternative Specifications of Scheduling Delay Components: The Effect of Travel Time Uncertainty and Departure Time Rescheduling. The 85th TRB Annual Meeting. Washington, DC, USA.

Vickerman, R.W., Spiekermann, K., Wegener, M., 1999. Accessibility and economic development in Europe. *Regional Studies* 33, 1–15.

Vreeker, R., Nijkamp, P., Ter Welle, C., 2002. A multicriteria decision support methodology for evaluating airport expansion plans. *Transportation Research Part D* 7, 27–47.